Defenders of the Black Hills

P. O. Box 2003, Rapid City, SD 57709 Phone: (605) 399 -1868

Dec. 26, 2008

Eric Holm
Natural Resources Project Engineer
Minerals and Mining Program
Sd Dept. of Environment and Natural resources
523 East Capitol
Joe Foss Building
Pierre, SD 57501-3181

Dear Mr. Holm,

Enclosed please find a "Request for Determination of Special, Exceptional, critical, or Unique Lands" including all the required information and exhibits.

Copies of this information has been sent to the list of agencies as well as the Custer and Fall River Counties Register of Deeds offices.

If you require further information, please call me at 605-399-1868.

Thank you.

Sincerely,

Charmaine White Face

Charmaine White Face, Coordinator

Department of Environment and Natural Resources
Minerals and Mining Program
Joe Foss Building
523 East Capitol Avenue
Pierre, SD 57501-3182

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DEC 29 2008
MINERALS & MINING PROGRAM

Request for determination of Special, Exceptional, Critical, or Unique Lands

(1.) Nominator: Defenders of the Black Hills
Charmaine White Face, Coordinator
PO Box 2003
Rapid City, SD 57709
Phone: 605-399-1868

(2) Legal description and County:

The lands being nominated are located within Custer and Fall River Counties. In Custer County the lands are located in T6S-R1E:

Section 20: E2NE4, E2SE4, SW4SE4, S2NW4SE4, SE4SW4, S2NE4SW4
Section 21: W2, W2W2NE4, W2NW4SE4
Section 27: S2
Section 28: N2NW4, SW4NW4, SW4
Section 29
Section 30
Section 31: E2
Section 32
Section 33: NW4, SW4 SE4 S2NE4
Section 34
Section 35

In Fall River County the lands are located in T7S-R1E:

Section 1
Section 2
Section 3
Section 4: W2W2
Section 5
Section 10
Section 11
Section 12
Section 14: NW4, W2NE4, NE4NE4
Section 15: N2

Name and Address of Surface Owner

The following are considered to be the Surface Owners*:

Bakewell-Andis Ranch, LLP
16730 East Inca Avenue
Fountain Hills, AZ 85268-4524

Chris and Amy Daniel
550 E. Sawgrass Trail
Dakota Dunes, SD 57049

Daniel Properties, LLC
c/o Chris Daniel
550 E. Sawgrass Trail
Dakota Dunes, SD 57049

GCC Dacotah, Inc.
501 North St. Onge Street
Rapid City, SD 57702
Copy to:
James S. Nelson, Esq.
Gunderson, Palmer, Goodsell & Nelson
P.O. Box 8045
Rapid City, SD 57709-8045

Putnam & Putnam LLP
c/o John A. Putnam
778 Cedar Street
Dewey SD 57735

Donald & Pat Spencer
27269 Elbow Canyon Road
Edgemont SD 57735-7613

Everett and Dawn Englebert
27449 Dewey Road
Burdock, SD 57735

Estate of Herman P. Heck
Attn: Keith Campbell
2630 Jackson Blvd.
Rapid City, SD 57702

Peterson & Son, Inc.
c/o Wayne Peterson
27389 Burdock Loop
Edgemont, SD 57735

Putnam & Putnam Partnership
c/o John A. Putnam
778 Cedar Street
Dewey SD 57735

US Dept. of Interior
Bureau of Land Management
310 Roundup St.
Belle Fourche SD 57717

Name and Address of Mineral Owner

The following are considered to be the Mineral Owners*:

Irene R. Andersen
27360 S. Flat Top Road
Edgemont SD 57735

Black Stone Minerals Company, L.P.
1001 Fannin, Suite 2020
Houston TX 77002-6709

Daniel Properties, LLC
c/o Chris Daniel
550 E. Sawgrass Trail
Dakota Dunes, SD 57049

Richard Elston
3312 W. Connaught
Spokane WA 99208

Estate of Herman P. Heck
Attn: Keith Campbell
2630 Jackson Blvd.
Rapid City SD 57702

Bakewell-Andis Ranch, LLP
16730 East Inca Avenue
Fountain Hills AZ 85268-4524

Chris and Amy Daniel
550 E. Sawgrass Trail
Dakota Dunes, SD 57049

Elston Bros. Realty Co. LLC
2227 S.185th St.
Omaha NE 68130

Everett & Dawn Englebert
27449 Dewey Road
Burdock SD 57735

Jean Swirczynski
PO Box 1848
Casper WY 82602

Roy Guess
1865 Beverly St., Apt. 101
Casper WY 82602

Agnes Medsker
62 Cypress Circle
Port Angeles WA 98362-9104

Peterson & Son, Inc.
c/o Wayne Peterson
27389 Burdock Loop
Edgemont SD 57735

Putnam & Putnam. LLP
c/o John A. Putnam
778 Cedar Street
Dewey SD 57735

Putnam & Putnam Partnership
c/o John A. Putnam
778 Cedar Street
Dewey SD 57735

Donald & Pat Spencer
27269 Elbow Canyon Rd.
Edgemont SD 57735-7613

Name and Address of Surface Owners Within 500 Feet of the Proposed Mining Operation

The following are considered to be Surface Owners with 500 feet*:

Hell Canyon Ranger District, BHNF
1225 Washington
Newcastle WY 82701

Clayton J. Sander
12469 Willow Creek
Custer SD 57730

SD School & Public Lands
500 E. Capital Ave.
Pierre SD 57501

Craig Stodart
HCR 59 Box 42
Edgemont SD 57735

(3) Map identifying the boundaries of the nominated lands

See attached map. This is the same map as provided in the application submitted by Powertech(USA) Inc.

(4) Description of the nominator's interest in the lands being nominated for inclusion on the preliminary list

According to 74:29:10:15. Clearance. "The lands described in a notice of intent to operate shall be considered cleared for special, exceptional, critical, or unique land characteristics if the department determines that the lands **do not** constitute special, exceptional, critical, or unique land and **no nominating petitions** pertaining to lands described in the notice are filed." [Author's emphasis] This is a nominating petition to include the land described in this application as special, exceptional, critical, or unique.

Using Webster's dictionary of definitions:
<u>Special</u> is defined as: distinguished by some unusual quality; peculiar; additional, extra; …for a particular purpose or occasion.
<u>Exceptional</u> is defined as: one that is excluded as, or having the quality of being rare…better than average; superior.
<u>Critical</u> is defined as: of, or relating to, or being a turning point or specially important juncture…about to change; crucial, decisive, indispensable.
<u>Unique</u> is defined as: single, sole; being without a like or equal; unequaled…(so-called "one of a kind"…or at least very rare).

The nominator's interest in the lands being placed in the list of special, exceptional, critical, or unique is based on the following:

Cultural Resources: The large number of cultural resources in the area must be protected and cannot be mitigated or restored once disturbed. These are special, exceptional, critical, unique antiquities that must be preserved and protected especially as there are so many in one location. According to Teton Sioux oral tradition, the area being nominated was used as a burial grounds, at least for the Teton Sioux, but also for other Indigenous nations in North America.

Species Protection: The area being nominated in this petition is home to at least one small family of bald eagles which is listed in South Dakota's threatened or endangered species. The bald eagles survival in the United States has been precarious for decades, and to destroy even one nest is to promote the extinction of this species that is a symbol of the United States. A place where a naturally occurring nest is found is special, exceptional, critical, and unique and must be protected and preserved as well as the food source area immediately surrounding the nesting site. Agricultural operations will not have an adverse effect, but any kind of development that includes machinery, prolonged human presence, or disturbance and removal of the food source will destroy the nesting site and eradicate future progeny.

Water Protection: The nominated area is within the recharge area of many aquifers that traverse the Region, and also a river that eventually empties into the Missouri River. To allow any kind of pollution into these water systems will eventually contaminate the entire system which is special, exceptional, critical, and unique for the Upper Midwest Region. The water systems must be protected and preserved.

(5) Statement of reasons for establishing the proposed boundaries

Although the nominator would prefer to include a much broader area, at this time, the area as shown on the map within the exterior boundaries is the area being nominated for listing and protection as special, exceptional, critical, and unique lands as this is the area that is being considered for potential human disruption and destruction.

(6) List and describe the characteristics of SDCL 45-6B-33.3 that apply to the nominated lands with supporting evidence

"For the purposes of Section 45-6B-33, land is special, exceptional, critical or unique if it possess **one or more** of the following characteristics…" [Author's emphasis]

"(1) The land is so ecologically fragile that, once it is adversely affected, it could not return to its former ecological role in the reasonably foreseeable future;

"(2) The land has such a strong influence on the total ecosystem of which it is a part that even temporary effects felt by it could precipitate a system-wide ecological reaction of unpredictable scope or dimension; or

"(3) The land has scenic, historic, archaeologic, topographic, geologic, ethnologic, scientific, cultural or recreational significance."

Water is the link and essential in all ecosystems. Because the land area in this nomination is usually very dry, consequently very fragile, the flora and fauna living here have adapted to this ecology. It is because of the sparcity of water, that all water in this area is precious and any adverse effects will harm all living organisms. Adverse effects would include exploratory well drilling to any depth, and open-pit mining through which runoff water pours onto surface areas, or seepage into the ground water. Any type of pollution to the water, both surface and ground, will have an irreversible impact not just on the local ecosystem, but as shown in Listing Petition Evidence Exhibit No. 1, in this case, pollution will have an impact on the ecosystems of the entire state and greater region.

The nominated area plays a small part in the recharge are of many aquifers. (See Listing Petition Evidence Exhibit No. 1) These aquifers have an influence on the entire state of South Dakota. As stated on page 299 of Exhibit 1, "The Dakota aquifer in South Dakota is the classic artesian aquifer. Many modern ideas concerning atesian aquifers stem from M.H. Darton's investigation of the Dakota aquifer during the 1890s and early 1900s. Darton recognized that the recharge to the system occurred in the Black Hills in western South Dakota while the major discharge was in eastern South Dakota, 300-500 km to the east."

Darton further stated "Another factor which undoubtedly somewhat influxes the hydraulic grade in the Great Plains region is a certain but unknown amount of general leakage through the so-called impermeable strata, especially when under great pressure."

Therefore any disturbance in the nominated area to the groundwater, no matter how small, will have an eventual effect on the entire state. Any disturbance of radioactive materials will have an effect lasting millions of years which is much longer than the "reasonably foreseeable future."

As most of the water use in western and much of eastern South Dakota, and particularly in the nominated land area, comes from wells tapped into the groundwater, it would behoove the protection of all groundwater. "Wellhead protection emphasizes the prevention of drinking water contamination as a principal goal, rather than relying on correction of contamination once it occurs…" as stated by the Environmental Protection Agency.. (See page 18, Exhibit 2)

Because of the effects on the water alone which answers (1) and (2) of Section 45-6B-33.3, this land area must be listed as special, exceptional, critical or unique as any disturbance will have a far reaching and long lasting effects that would precipitate a system-wide ecological reaction of unpredictable scope or dimension.

Regarding Cultural Resources, in the Aug.20, 2008, Powertech (USA) Inc. submittal of a "Request for Determination of Special, Exceptional, Critical, or Unique Lands and Intent to Operate" form, page 10, states that a level III Cultural Resources Evaluation was conducted by the Archeology Laboratory, Augustana College, Sioux Falls, SD.

"The small number of Euroamerican sites documented was notunantidcipated given the peripheral nature of the projet area in relation to the Black Hills proper. The disparity existing between the number of historic [since 1874 - author's note] and prehistoric sites observed in the project area is also not unexpected; however, **the sheer volume of sites documented in the area is noteworthy.** [Author's emphasis] The land evaluated as part of the Level III cultural resources evaluation has an average site density of approximately 1 site per 8.1 acres. Even greater site densities were reported in 2000 during the investigation of immediately adjacent land parcels for the Dacotah Cement/bnd exchange [Winham et al., 2001]. This indicates that the permit area is not unique, in regards to the number of documented sites, and is typical of the periphery of the Black Hills."

However, it also indicates that this is a very special, exceptional, critical and unique area in the number of antiquities that are located there. Many other places in the world prize their areas of ancient treasures that are irreplaceable and protect and preserve them to their best ability. This land area being nominated by Defenders of the Black Hills is just such a rare treasure and must be protected and preserved by being listed as a special, exceptional, critical and unique land area.

Finally, regarding state listed threatened or endangered species, in a letter dated Oct. 17, 2008, to the SD Department of Environment and Natural Resources, the South Dakota Game, Fish, and Parks stated that no activity should be conducted on the land discussed in this request, for 7 months per year, between Feb. 1st to Aug. 31st, "…to avoid disruption of bald eagle activity at the nest" and also because of a nearby redtail hawk nest. (See Exhibit 3) This does not address other threatened or endangered species such as the long-billed curlew (Numenius americanus), the golden eagle (Aquila chrysaetos), merlin (Falco columbarius), Cooper's hawk (Accipiter cooperii), American white pelican (Pelicanus erythrorhynchos), and long-eared owl (Asio otus).

The fact that there is a place in South Dakota with enough food and water to sustain a breeding bald eagle nest when South Dakota recognizes the threatened and endangered status of the bald eagle should be enough to declare this nominated land area a special, exceptional, critical and unique land area. The fact that other species can also be found in this same area gives further credence to need to protect and preserve the special, exceptional, critical and unique environment that they all need to continue to survive. These kinds of places are becoming more and more threatened with the increasing human population. The survival of what is remaining of these species depends on long range foresight and planning by human beings. It is very crucial that the land area nominated in this request be listed as special, exceptional, critical or unique lands in South Dakota.

(7) Signature of Nominator with witness by Notary Public

I declare and affirm under the penalties of perjury that this claim (petition, application, information) has been examined by me, and to the best of my knowledge and belief, is in all things true and correct.

Signature Charmaine White Face

Title Coordinator **Date** Dec. 26, 2008

* Disclaimer: Defenders of the Black Hills' position on land ownership is that all lands in this application are still the legal property of the Great Sioux Nation as stated in the Fort Laramie Treaty of 1868 and protected by Article VI of the Constitution of the United States, and the March 3rd Act of 1871. Participation in this process of the SD Department of Environment and Natural Resources does not constitute relinquishment of that position.

STATE OF South Dakota

COUNTY OF Pennington

On this 26 day of December, 2008, before me personally appeared Charmaine White Face who acknowledged himself to be Coordinator (Title) for Defenders of the black Hills (Operator)

and that he is authorized to execute this Request for Determination of Special, Exceptional, Critical, or Unique Lands and Notice of Intent to Operate for the purposes contained therein.

Shelley Tubbs
Notary Public

My Commission Expires My Commission Expires May 13, 2014

SEAL

SEAL SHELLEY TUBBS NOTARY PUBLIC State of South Dakota SEAL

FOR DEPARTMENT USE ONLY

The land described in this Request for Determination of Special, Exceptional, Critical, or Unique Lands and Notice of Intent to Operate ( ) is ( ) is not eligible for inclusion on the list of special, exceptional, critical, or unique lands.

______________________________ Date ______________

Secretary, Department of Environment and Natural Resources

Operator Appeal Date ______________

Intervenor Contest Date ______________

The land described in this Request for Determination of Special, Exceptional, Critical, or Unique Lands and Notice of Intent to Operate ( ) is ( ) is not eligible for inclusion on the list of special, exceptional, critical, or unique lands.

______________________________ Date ______________

Chairman, SD Board of Minerals and Environment

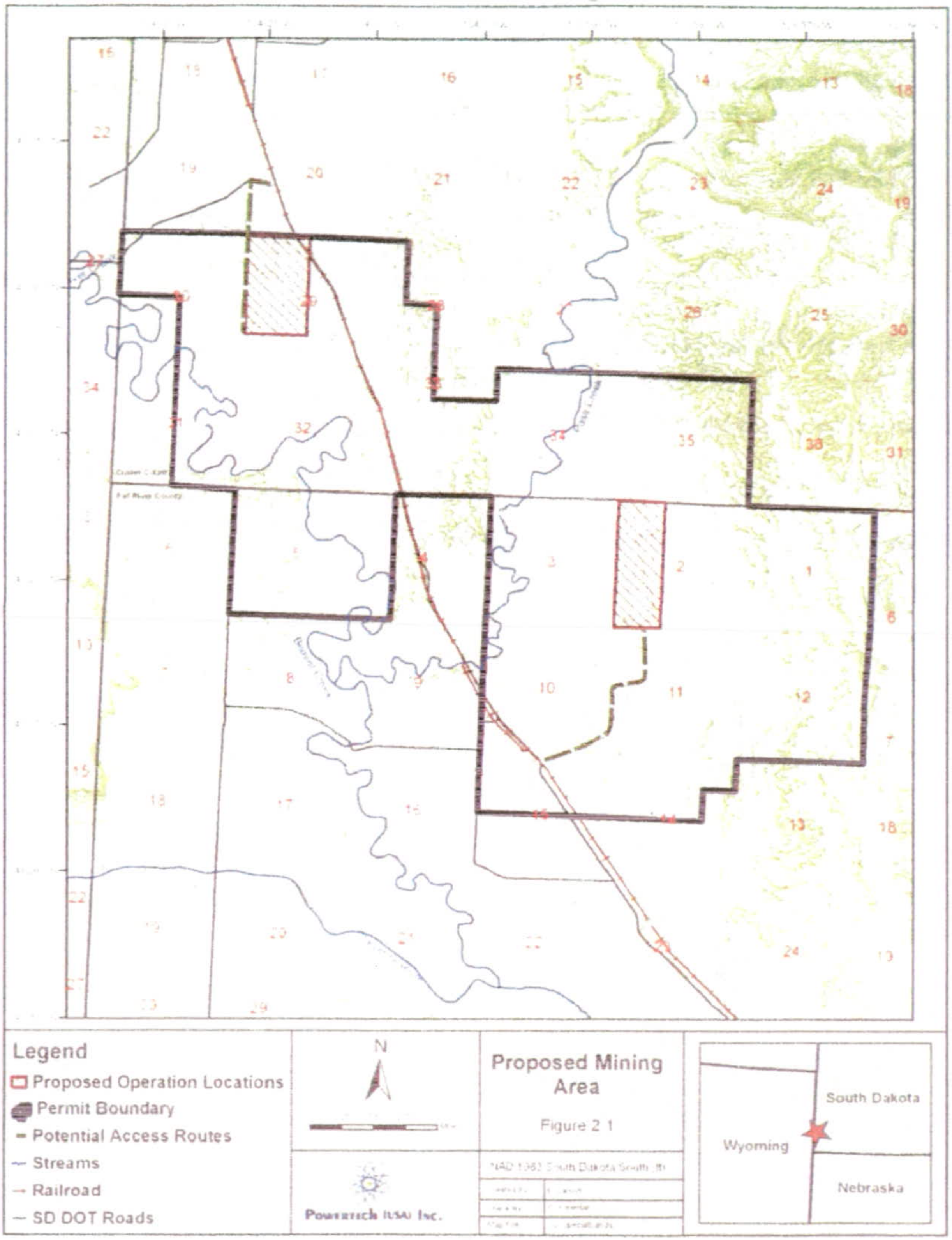

Figure 2-1. Proposed Mining Area With Proposed Facility Locations and Potential Access

LISTING PETITION EVIDENCE EXHIBIT - 1

Geological Society of America
Special Paper 189
1982

Regional Ground-Water Flow Concepts in the United States: Historical Perspective

J. D. BREDEHOEFT
W. BACK
B. B. HANSHAW
U.S. Geological Survey, 431 National Center
Reston, Virginia 22092.

ABSTRACT

A number of important ideas, developed during the past 100 years, form the framework of the present understanding of regional ground-water flow. The most important of these ideas are:

1. Differences in topographic elevation provide the principal driving force for regional flow.
2. Flow through confining layers forms an essential element of regional flow systems.
3. Chemical evolution within the flow systems can be used to understand the flow.
4. Moving ground water is an efficient transport mechanism for heat within the Earth.

We trace the evolution of these ideas in the United States and demonstrate their influence on the present-day understanding of flow systems with examples taken primarily from the American literature.

INTRODUCTION

A number of regional flow systems have been investigated since Darton first studied the Dakota sandstone. In this paper, we review significant ideas developed in North America that have led to the present understanding of regional ground-water flow and geochemistry, and suggest some ideas for present and future research. We do not claim that the review is complete; we accept that we may have omitted investigations or ideas that others feel are as important as those we included.

Several important ideas now provide a fundamental understanding of the phenomenon of regional flow. The most important of these ideas, which we might refer to as the principles that govern regional flow, are:

1. Differences in hydraulic head produced by topographic relief on the boundaries of the flow system are, in most instances, the driving force for the flow.
2. Most naturally occurring earth materials have finite permeability; there are no totally impermeable materials. In sedimentary deposits significant quantities of flow commonly occur through shaley confining layers.
3. Chemical reactions within the flow system occur in the moving fluid--ground water. The chemical evolution within the system can be utilized to understand the flow better.
4. Moving ground water is an efficient mechanism for the transport of heat within the Earth's crust. In areas of significant flow the natural conductive heat flux in the Earth is disturbed.
5. Regional ground-water flow plays an important role in the movement and entrapment of hydrocarbons.
6. Shales within the Earth may act as semipermeable membranes that retard the passage of charged species (ions) while allowing relatively unrestricted passage of neutral molecules (water). The pheonomenon can cause anomalously high or low osmotic pressures, electrical potential differences, and salt sieving or ultrafiltration.

MATHEMATICAL FRAMEWORK

The total concept of regional flow systems implies an understanding of the interrelations of hydrodynamics and geochemistry. In ground water we are concerned with the fluids contained in the aquifer system. That fluid is generally described by stating (1) pressure, (2) composition, and (3) energy contained in the fluid. In the general case, three coupled partial differential equations are used to describe the system:

1. A partial differential equation for pressure, which in certain simplifying instances can be reduced to an equation for hydraulic head; this is commonly referred to as the flow equation

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2. A partial differential equation for chemical composition; in the case where more than one chemical constituent of the fluid is of interest, this becomes a set of partial differential equations

3. A partial differential equation for the internal energy of the fluid, generally either the temperature or the enthalpy of the fluid.

In the most general case fluid pressure, composition, and internal energy are coupled as are the equations (or sets of equations) that describe the state of the fluid. However, in many instances the coupling may be negligible and the state variables can be treated independently. For example, in many problems the change in temperature is unimportant and we consider the system isothermal, eliminating internal energy considerations.

Ground-water flow, in the most general case, is three dimensional and varies with time; to describe the system the following must be specified completely:

1. Spatial distribution of the parameters contained in the three (or more) partial differential equations mentioned above
2. Initial conditions for pressure, composition, and temperature, or enthalpy
3. Source and sinks of interest and their variation with time
4. Boundary conditions at the margins of the space of interest

Parameters of Governing Equations

Each of the governing equations contains parameters that describe certain properties of aquifers and confining layers that affect ground-water flow, chemical composition, and internal energy.

Parameters affecting flow. For flow problems in which we neglect effects of composition and temperature (internal energy) or the density, the parameters of interest are porosity; permeability; and specific storage, which reflects the combined compressibility of the fluid and the medium.

Parameters affecting chemical composition. These are related to problems of fluid composition and include dispersion coefficient, which most investigators formulate as a function of the fluid velocity and a property of the medium dispersivity; and the coefficient of molecular diffusion for the constituent in a porous medium.

Parameters affecting internal energy. Energy transport includes an additional parameter: thermal dispersivity for energy transport, which is generally thought to have a form similar to that of dispersivity for composition. The dispersivity for energy may have a different magnitude than for composition; there are, however, few empirical data. The heat capacity of the aquifer material and water is another parameter that affects internal energy, for it governs the amount of energy that can be stored within the system.

Initial Conditions

To compute transient system response, the distribution of pressure, composition, and internal energy (temperature or enthalpy) must be specified at some initial time.

Sources and Sinks

In the usual case the most important sources and sinks are:

1. Recharge or discharge, commonly through wells. Other natural recharge or discharge may also be handled as sources and sinks depending upon how the problem is formulated mathematically.
2. Chemical reactions, which either remove or add components to the fluid. This is one of the more troublesome problems since one must know what reactions are occurring as well as the rate of each reaction.

Boundary Conditions

In ground-water problems, the boundary conditions of most interest are:

1. No flux, that is, an impermeable boundary.
2. Prescribed flux, where the flow at the boundary is given some value; commonly for problems involving composition, a given composition of a particular constituent; and for energy problems, a given temperature or enthalpy.
3. Prescribed value of the state variable, where for flow the head or pressure is defined; for composition a constituent concentration is defined; and for energy either the temperature or enthalpy is defined.

In summary, each of the parameters described above, which characterize the media, can vary through space. Permeability and dispersivity for both composition and energy can have directional properties at any point in space. The value of each of the parameters must be specified throughout the region of interest if the system is to be understood quantitatively. It is from an understanding of all aspects of the geology of aquifer systems that we define the geometry and the distribution of the parameters in space, as well as define the boundary conditions.

Each of the state variables: (1) pressure or head, (2) chemical composition, and (3) temperature complement each other and can be used to investigate regional flow. As the following discusson will demonstrate, the interactions of the state variables have been used by various investigators to study regional flow.

REVIEW OF SELECTED STUDIES ON REGIONAL FLOW CONDITIONS

In 1885, T. C. Chamberlain published *The Requisite and Qualifying Conditions of Artesian Wells*, which is perhaps the first classic paper on regional flow. His discussion of "confining beds" (p. 137-138) is particularly appropriate:

> No stratum is entirely impervious. It is scarcely too strong to assert that no rock is absolutely impenetrable to water. Minute pores are well nigh all-pervading. To these are added microscopic seams, and to these

again larger cracks and crevices. Consolidated strata are almost universally fissured. Even clay beds are not entirely free from partings. But in the study of artesian wells we are not dealing with absolutes but with availables. A stratum that successfully restrains the most of the water, and thus aids in yielding a flow, is serviceably impervious. It may be penetrated by considerable quantities of water, so that the leakage is quite appreciable and yet be an available confining stratum.

This is an important idea in our current thinking but, unfortunately, each generation of ground-water hydrologists seems to have to rediscover this thought.

One of the early studies of regional flow was that of Mendenhall (1905) in the Los Angeles area of California; Mendenhall described the regional flow over much of the San Bernardino Valley and related the flow to the topography and the alluvial geology of the valley.

The Dakota aquifer in South Dakota is the classic artesian aquifer. Many modern ideas concerning artesian aquifers stem from N. H. Darton's investigation of the Dakota aquifer during the 1890s and early 1900s. Darton recognized that the recharge to the system occurred in the Black Hills in western South Dakota while the major discharge was in eastern South Dakota, 300 to 500 km to the east. Darton (1896) wrote a preliminary report which described the system. He, and colleagues under his direction, proceeded to map systematically the area of principal development along the James River in eastern South Dakota; much of the actual mapping was done by J. E. Todd under Darton's direction. This resulted in a series of Geologic Folios, which covered the ground-water geology of the James River lowland from Nebraska to North Dakota; these folios were obviously designed to display the ground-water geology of the area under development. These are still classic examples of hydrogeological mapping. While Todd mapped the area of major development, Darton mapped the four quandrangles that encompassed the entire Black Hills, and included the areas of Dakota outcrop that he believed to be the recharge area for the Dakota aquifer in South Dakota. Darton (1909) summarized his Dakota investigations in USGS Water Supply Paper 227 in which he pointed out that potentials within the Dakota system are controlled by the elevation of the sandstone outcrops in the Black Hills. Darton (1909, p. 60) set forth his ideas concerning the mechanics of the system in the following remarks:

> The evidence of this pressure, as found in many wells in eastern South Dakota, is conclusive that the water flows underground for many hundreds of miles. Such pressures can be explained only by the hydrostatic influence of a column of water extending to a high altitude on the west. If it were not for the outflow of the water to the east and south the initial head which the waters derive from the high lands of the intake zone would continue under the entire region, but owing to this leakage the head is not maintained, and there is a gradual diminution toward the east known as "hydraulic grade," a slope sustained by the friction of the water in its passage through the strata.

Obviously, Darton fully understood that some water must flow through the overlying confining layers; he goes on to state (Darton, 1909, p. 60):

> Another factor which undoubtedly somewhat influences the hydraulic grade in the Great Plains region is a certain but unknown amount of general leakage through the so-called impermeable strata, especially when under great pressure.

Although Darton's ideas of the mechanics of the Dakota system, especially of the flow through the confining layer, were explicit, these ideas seem to have become lost in the intervening years.

Many of our modern ideas of the hydrology of artesian aquifers originate in these investigations of Darton and his colleagues. Most elementary geology texts use Darton's illustrations of the Dakota sandstone to introduce the idea of artesian flow.

The mechanics of flow in the Dakota aquifer in South Dakota became the subject of major debate in the late 1920s. A number of prominent geologists, including Meinzer, participated in the discussion. This debate, while focusing on the Dakota sandstone, became a forum for discussing the thinking of the 1920s on flow through major aquifer systems.

Russell (1928), following extensive stratigraphic study of the Dakota in the outcrop area in eastern South Dakota, questioned Darton's explanation of the artesian pressures. Russell observed that the sandstones which crop out in the Black Hills differ in age from those that comprise the aquifer in eastern South Dakota. He also pointed out the distinct variations in the chemistry of the Dakota water. Based upon this evidence, Russell suggested that the sandstones were lenticular and that the artesian pressure was the result of a reduction in pore volume within the sandstone due to sedimentary loading. Russell's paper excited considerable discussion. Terzaghi (1929) examined Russell's mechanism in light of the theory of consolidation and concluded that Russell's suggested mechanism was most improbable.Piper (1928) questioned Russell's stratigraphy and reiterated that the aquifer sandstones were probably continuous.

At the time of Russell's paper, Meinzer (1928) had a paper in press which suggested that the artesian head supports a portion of the load of the overlying rocks and that aquifers undergo small changes in pore volume as the result of changes in head. He further stated that some part of the water discharged from wells drilled in the 1890s and early 1900s to the Dakota was derived from this elastic change in pore volume. This was the first clear statement of storage in an artesian system. It is evident from pre-1928 correspondence between Meinzer and Dave Thompson, who was working in New Jersey, that Meinzer's ideas were based to a large extent upon discussions with Thompson. Thompson (1929) discussed both Meinzer's (1928) and

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more-permeable units in controlling the hydrodynamics of the system. As first stated by Chamberlin (1885), confining layers are not impermeable. The areal extent of most major systems is such that even though the permeability of the confining layers is low, significant quantities of water move through these layers. Nevertheless, not until the 1940s did ground-water hydrologists fully recognize the concept of leaky confining layers. Jacob (1946) and Hantush (1960) considered the influence of leakage on pumping and showed that in many areas of ground-water development, the magnitude of the leakage determines the ultimate size of the development. However, the permeability of the confining layers is one of the more difficult parameters to determine.

Today, our concept of regional flow allows for large quantities of both discharge and recharge to occur by movement through the confining layer. Current thinking suggests that the major discharge from the deeper permeable formations of the Illinois Basin, for instance, is by upward vertical flow through the confining layers (Bredehoeft and others, 1963; Graf, 1960). The same is true for discharge from the Tensleep Sandstone in the Big Horn Basin of Wyoming where a nearly closed depression in the potentiometric surface for the Tensleep is best explained by upward vertical movement of fluid (Fig. 4). The Carrizo sandstone also apparently discharges by means of vertical leakage (Pearson and White, 1967). Based on sulfur isotope data, Hanshaw and others (1978) have suggested that most of the water currently being produced from wells open to the Madison limestone in the Midwest area of Wyoming is leaking downward from Pennsylvanian and Permian beds.

Along the Atlantic coast between Savannah and Jacksonville the Floridan aquifer and its equivalent in Georgia contain heads near the coast that range from 10 to 20 m above sea level (see Fig. 1). This can only be explained as the consequence of a low permeability confining layer overlying a highly permeable aquifer. In studies of the "Floridan" aquifer at Brunswick, Georgia, Bredehoeft and Pinder (1973) have shown that by simulating the virgin steady-state flow system the permeability of the confining layers can be computed with reasonable precision.

Swenson (1968) reexamined the ability of the Dakota system, under existing hydraulic gradients, to transmit the quantity of water known to be produced in eastern South Dakota. He emphasized the differences in the chemistry of the Dakota water from the recharge area to the major area of production in the Missouri River valley. He suggested that cavernous limestones of the Madison group may be truncated by the lowermost sandstones of the Dakota aquifer in central South Dakota and that the bulk of Dakota water in eastern South Dakota is recharged from these underlying Madison group limestones. The suggestion that the Dakota is recharged by water from the Madison group limestones had been stated previously by Dyer and Geohring (1965) in an open-file study of the Dakota aquifer in southeastern South Dakota. Can the Dakota aquifer alone provide the quantities of water known to have been produced from the system or must one look for an additional source? This question is implied in each of the papers that followed Darton's classic of 1909. Implicit in Swenson's (1968) statements is the thought that

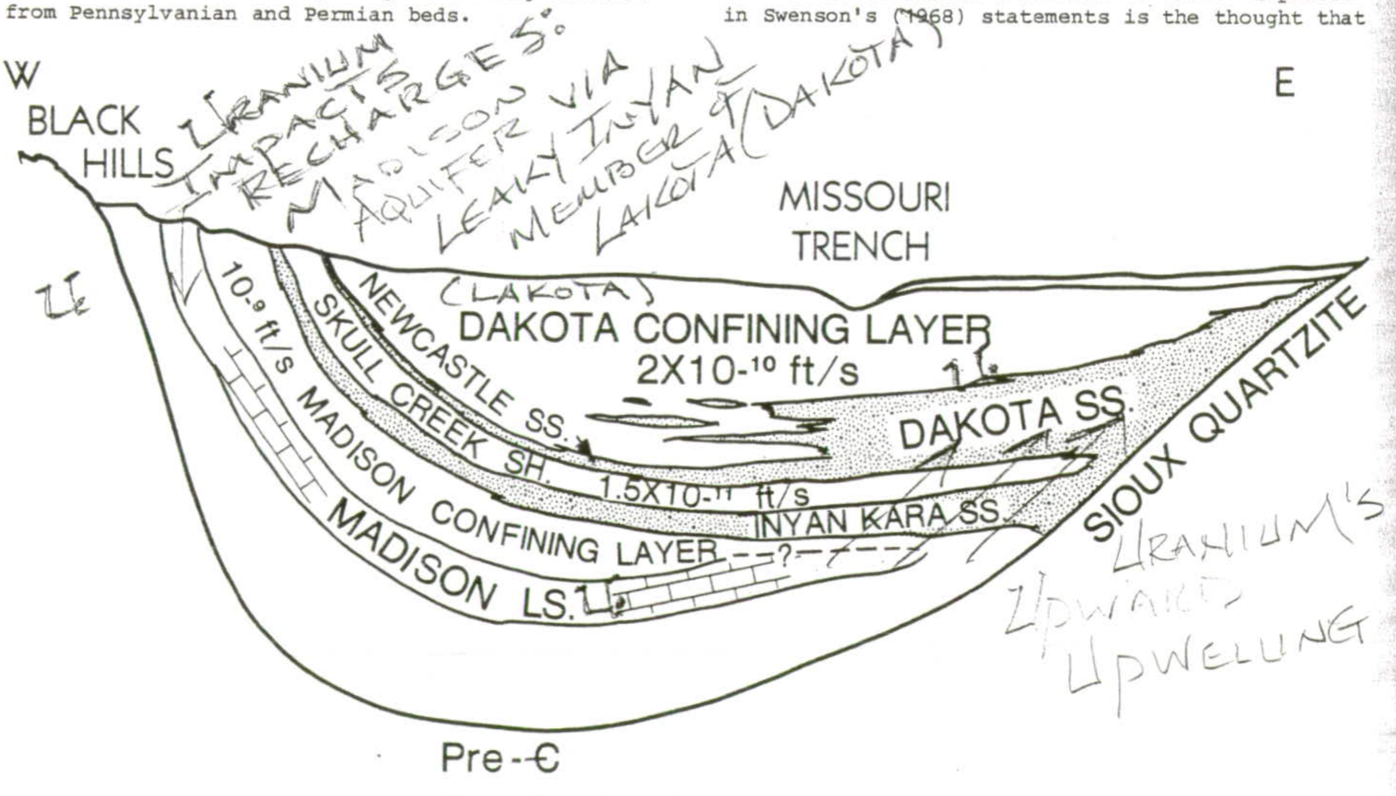


Figure 5. Schematic diagram of the Dakota aquifer system in South Dakota (after Neuzil, 1980).

← SOUTH DAKOTA →

← SOUTH DAKOTA →

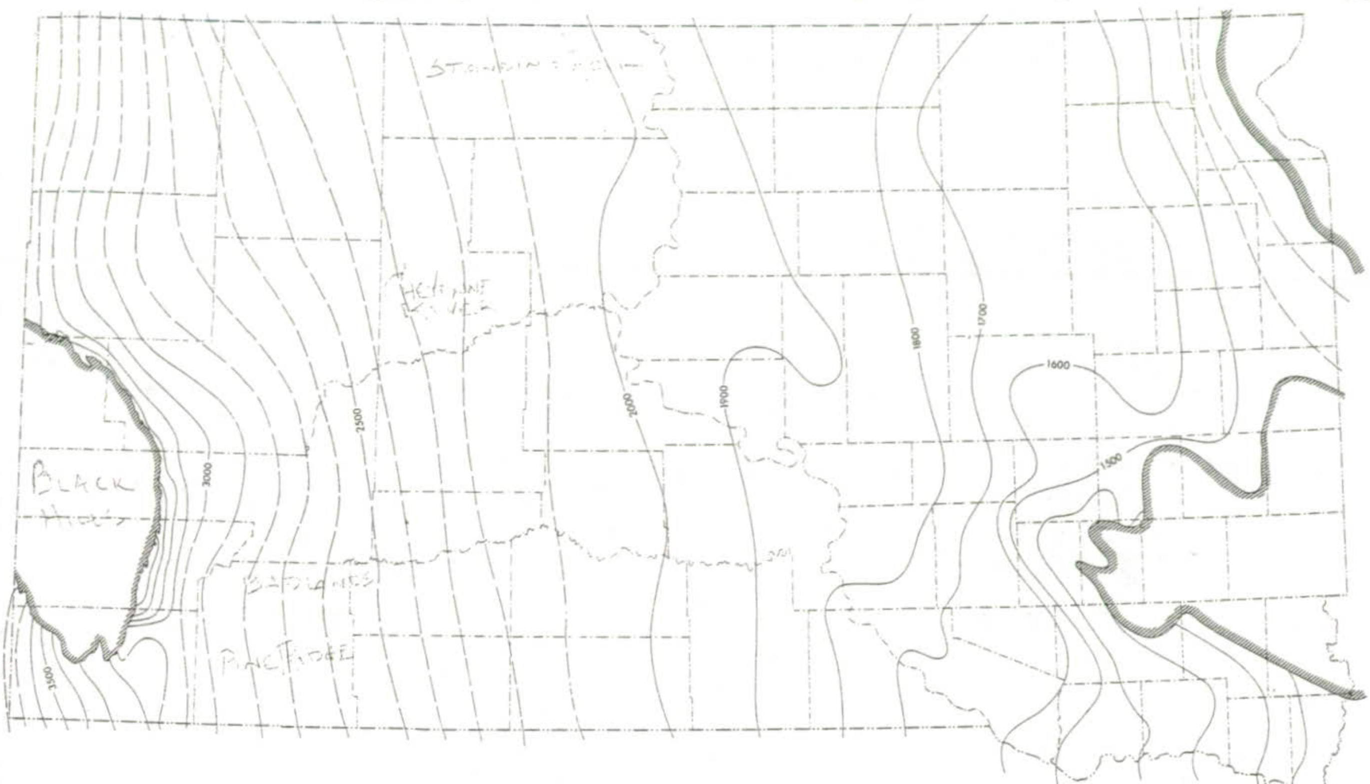


Figure 6. Darton's potential for the Dakota aquifer (Darton, 1909).

CONSTANT FLOW
G-W THRUPUT

the system is nearly in steady state, that is, little additional water is available from storage. Figure 5 is a simplified schematic diagram of the Dakota aquifer system in South Dakota.

Assuming that we know: (1) the physical geometry of the system (the geology); (2) the boundary conditions for the flow system; (3) the permeability of the aquifers; and (4) the virgin head distribution in the major aquifers of the system, we can compute the permeability of the confining layers.

These computations have been made numerically for the Dakota aquifer system in South Dakota and show that the computed head in the major aquifers is sensitive to the permeability of the confining layers. Darton's potential surface (1909), reflects the influence of major development along the Missouri River and the area east of the river (Fig. 6).

Figure 7 is the computed potential surface for the Dakota aquifer and, considering the influence of pumping, the comparison is good. This procedure yields a permeability for the confining layer which is as accurate as our knowledge of the aquifer permeability.

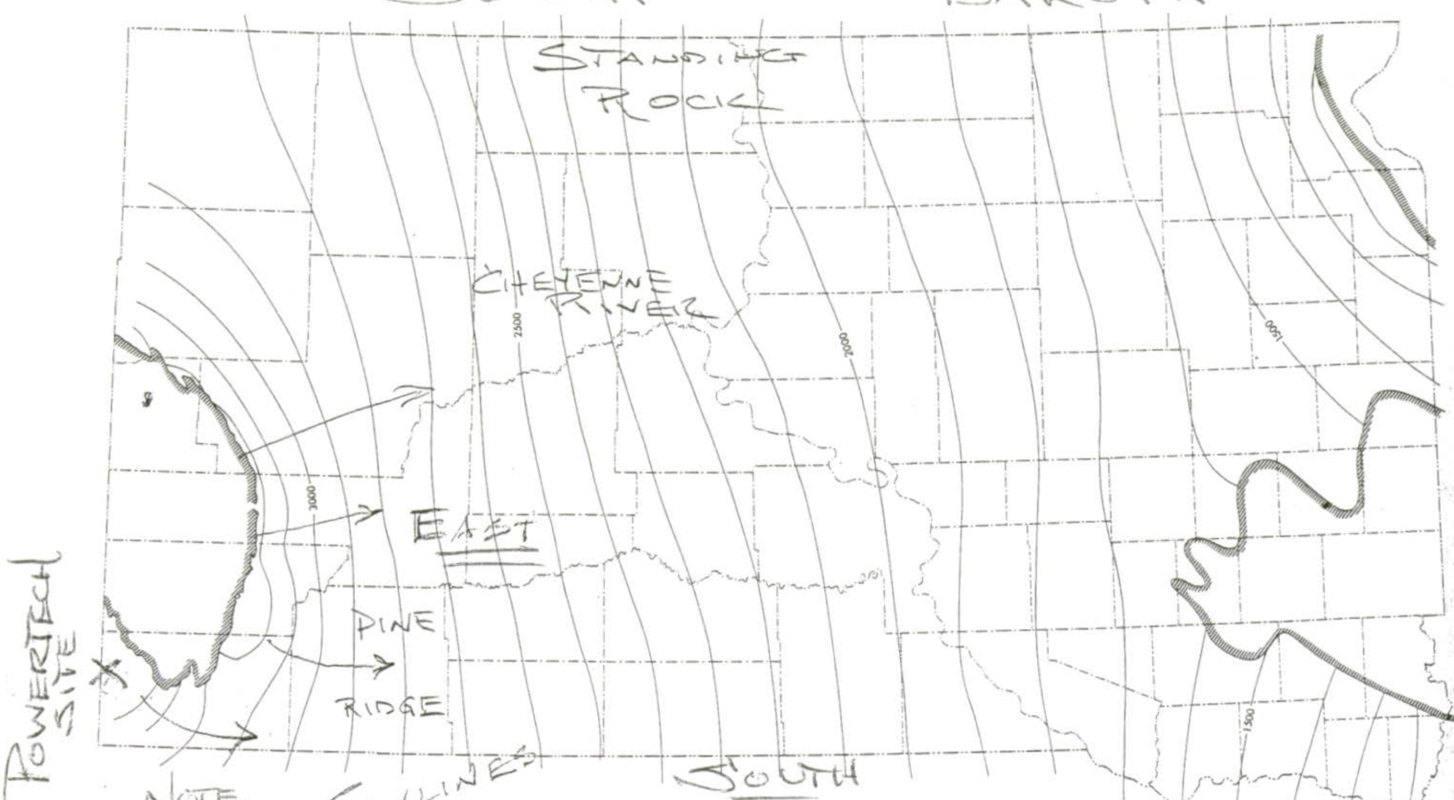
HYDRODYNAMICS OF OIL AND GAS ACCUMULATION

M. K. Hubbert, one of the pioneers of ground-water theory (1940) became interested in regional ground-water flow and in particular the influence of hydrodynamics on the accumulation of hydrocarbons. Hubbert (1953) demonstrated that dynamic ground water flow could trap hydrocarbons in geologic structures that would not be traps in a static ground-water regime; he named the phenomenon "hydrodynamic entrapment." A number of oil companies applied Hubbert's ideas; but unfortunately, little, if any, of the resulting information was published because of its proprietary nature.

Perhaps the most active group to study regional hydrodynamics was the group organized by Hill in the late 1950s and early 1960s at Petroleum Research Corporation. With an energetic and able staff, this group compiled potentiometric maps for many of the permeable lithologic units of the intermountain basins of the Rocky Mountain region and the Colorado Plateau. The work of Petroleum Research Corporation was supported by subscription from the major oil companies. These investigations demonstrated the occurrence of regional flow systems throughout the Rocky Mountain area. Although much of the work is proprietary and remains unpublished, Hanshaw and Hill (1969) published a regional interpretation of potentiometric surfaces in the Paradox Basin.

At the same time, urged by Hubbert, the U. S. Geological Survey began an investigation of the Tensleep Sandstone in the Big Horn Basin in Wyoming. This system is particularly interesting; it contains a number of oil traps with hydrodynamic tilts of the oil-water interface. Zapp (1956) examined the discovery and early production well data and published a map of the basin indicating the tilts. Bennett, working independently from Zapp, investigated the potentiometric surface for the Tensleep

← SOUTH DAKOTA →



NOTE → FLOWLINES INTO S.D.

Figure 7. Computed potential surface for the Dakota aquifer.

ΔH/ΔL GRADIENT

Sandstone in the Big Horn Basin (Bredehoeft and Bennett, 1971). This map (Fig. 4) indicates that the tilts of the oil-water interface mapped by Zapp were hydrodynamically controlled. This may be the most convincing published field evidence for Hubbert's hydrodynamic entrapment theory.

GEOCHEMISTRY OF REGIONAL FLOW SYSTEMS

The geochemistry of the water in aquifers reflects both the mineralogy and the reactions occurring along the water flow path; by understanding geochemical processes controlling the water chemistry, we obtain independent information on the nature of flow systems. This understanding requires (1) data on the spatial and stratigraphic distribution of the dissolved constituents and the controlling mineralogy; (2) recognition of hydrogeologic controls on this observed distribution; (3) identification of the chemical reactions that influence this distribution; and (4) data on rates of chemical reactions and transport of dissolved constituents. The philosophical and historical development of chemical geohydrology have been discussed by Hem (1959 and 1970), Back and Hanshaw (1965), Bredehoeft and Pinder (1973), and Back and Cherry (1976).

Many of the early chemical studies of ground water were primarily descriptive and were undertaken to determine the quality of water for various uses; the earliest concern was the potential for the water to form scale in steam boilers, both stationary engines and locomotives. Later the interest turned to quality requirements for irrigation, and then for use as municipal and industrial water supplies.

One of the first studies to demonstrate the hydrologic significance of chemical reactions is the classic paper by Foster (1950) in which she explained the origin of bicarbonate water in regional aquifers of the Atlantic Coastal Plain through the use of laboratory experiments. She demonstrated that carbonaceous material in the aquifer decomposed and generated carbon dioxide which facilitated the solution of calcium carbonate; the dissolved calcium was exchanged with sodium by "base-exchange" minerals in the aquifers to produce abnormally high concentrations of bicarbonate. Two papers by White (1957a,b) stimulated a great deal of interest and additional studies; he proposed a classification of "deep" waters based on their chemical and isotopic compositions. Although he did not use the term "regional flow system," this concept was implied in his duscussion of the origin of the various types of water identified--volcanic, magmatic, connate, and metamorphic.

Geochemical studies of water took an entirely new approach in the early 1960s with the application of the principles of chemical thermodynamics. Henri Schoeller (1956) in France had previously initiated similar work but his important contributions were generally unknown to American hydrologists. The potential value of chemical thermodynamics as applied to the study of ground water was not generally recognized by hydrologists in this country until the publications of papers by Hem and Cropper (1959), which showed the application of the Nernst equation to potable water, and by Back (1961), which demonstrated the application of the law of mass action to equilibrium principles and ground-water chemistry.

Back (1966) employed the concept of hydrochemical facies he had developed earlier; this was one of the first regional studies to couple an interpretation of chemical data with the ground-water flow regime. Hydrochemical facies depict the diagnostic chemical character of water in various parts of the system. The facies reflect the effects of chemical reactions occurring between minerals within the lithologic framework and ground water. The mineralogy of an aquifer system largely determines the type of hydrochemical facies that will develop; flow patterns modify the hydrochemical facies and control their distribution. By mapping the chemical character of water in the Atlantic Coastal Plain aquifers, Back was able: (1) to demonstrate use of chemistry to identify and understand the regional flow patterns, (2) to determine the controlling chemical reactions; and (3) to delineate areas where these reactions could be studied most effectively. The primary controls on the composition of the ground water were identified as being (1) chemical character of the water as it enters the zone of saturation; (2) distribution, solubility, and sorption capacity (ion-exchange) of the minerals in the deposits; and (3) the flow rate and path of the water. Seaber (1962) made a detailed regional geochemical study of the Coastal Plain aquifers in New Jersey in which he observed geochemical patterns that correlated with the general understanding the flow system.

Interpretation of the origin of the hydrochemical facies in the Coastal Plain aquifers demonstrated that certain principles of low-temperature geochemistry that were being applied to laboratory studies at that time, primarily by R. M. Garrels, had direct application to the ground-water regime. Specifically, those ideas are: (1) that mineral equilibria studies provide a geochemically meaningful description of ground water and (2) that oxidation-reduction (redox) potential is a major control on concentration and behavior of many constituents in ground water.

The concept of regional redox zonation (Back and Barnes, 1965) was demonstrated by integrating measurements of oxidation potentials and pH with the ground-water flow pattern to explain the occurrence and concentration of iron in various parts of an aquifer. This concept was further developed in the more complex Lincolnshire limestone in England by Edmunds (1973) in which he explained not only the concentration and distribution of metals but also of sulfate, sulfide, and nitrate. Champs and others (1979) compared such redox zones in four separate aquifer systems and named three biochemical zones on the basis of redox processes: oxygen-nitrate, iron-manganese, and sulfide.

The effect of local and regional flow on the chemistry of ground water was emphasized by Thrailkill (1968) in his study of formation of caves. Water in calcareous vadose zones is often saturated or supersaturated with respect to calcite; the water may become undersaturated and thereby capable of dissolving additional calcite by being cooled or by mixing with water that has a lower partial pressure of carbon dioxide. If the vadose zone above a carbonate aquifer lacks calcareous material, the recharge water will be undersaturated with respect to calcite and the water in the regional flow system will become saturated by dissolving calcite in the aquifer. White (1977) has formalized these basic ideas to develop conceptual models for carbonate aquifers in order to explain solution and permeability distribution in various flow systems.

Recent advances by carbonate petrologists and geochemists have provided additional insights into the distribution of porosity and permeability. An understanding of (1) the origin, chemistry, mineralogy, and environments of deposition and accumulation of carbonate sediments together with (2) a comprehension of diagenetic processes that change sediments to rocks, and (3) the geochemical, tectonic, and hydrologic processes that create voids make possible the prediction of regional porosity and permeability (Hanshaw and Back, 1979). Langmuir (1979) presented an example of reactions that control the chemical character of ground water in various parts of the flow system in carbonate aquifers; he showed that the water from springs was generally more undersaturated with respect to both calcite and dolomite than was the water from wells. The springs reflect the local, shallow flow system whereas the wells tap a deeper regional flow system.

Back and Hanshaw, working with others, have used the Floridan aquifer system as their principal field laboratory to investigate the goechemistry of a carbonate aquifer system. They have extended their ideas of relating carbonate equilibrium to regional ground-water flow to other systems--the Madison Limestone in the Northern Great Plains (Hanshaw and others, 1978) and the Yucatan Peninsula (Back and Hanshaw, 1970). Based on an interpretation of chemical data, they concluded that the characteristics of the regional flow in the artesian aquifer of Florida (Fig. 8) are controlled to a large extent by the permeability of the confining layer. The lack of regional flow in the Yucatan results primarily from absence of confining beds. In Florida the chemical character of water systematically changes downgradient as minerals dissolve until the water attains equilibrium, such as is shown with respect to calcite (Fig. 9). The saturation indices (log ion activity product/equilibrium constant) indicate the water is less saturated in the recharge areas and progressively becomes more saturated toward discharge points.

As a result of their regional aquifer studies in Florida, Hanshaw and others (1971) hypothesized that dolomitization could occur within carbonate aquifers in the zone where the discharging ground water mixes with salt water. The mixing provides a continuous supply of magnesium and produces undersaturation with respect to calcite and supersaturation of dolomite. Badiozamani (1973) named this ground-water mixing model "the dorag dolomitization model" and applied it in an excellent study to explain the origin of middle Ordovician dolomites of southwestern Wisconsin.

A series of papers on geochemistry of formation

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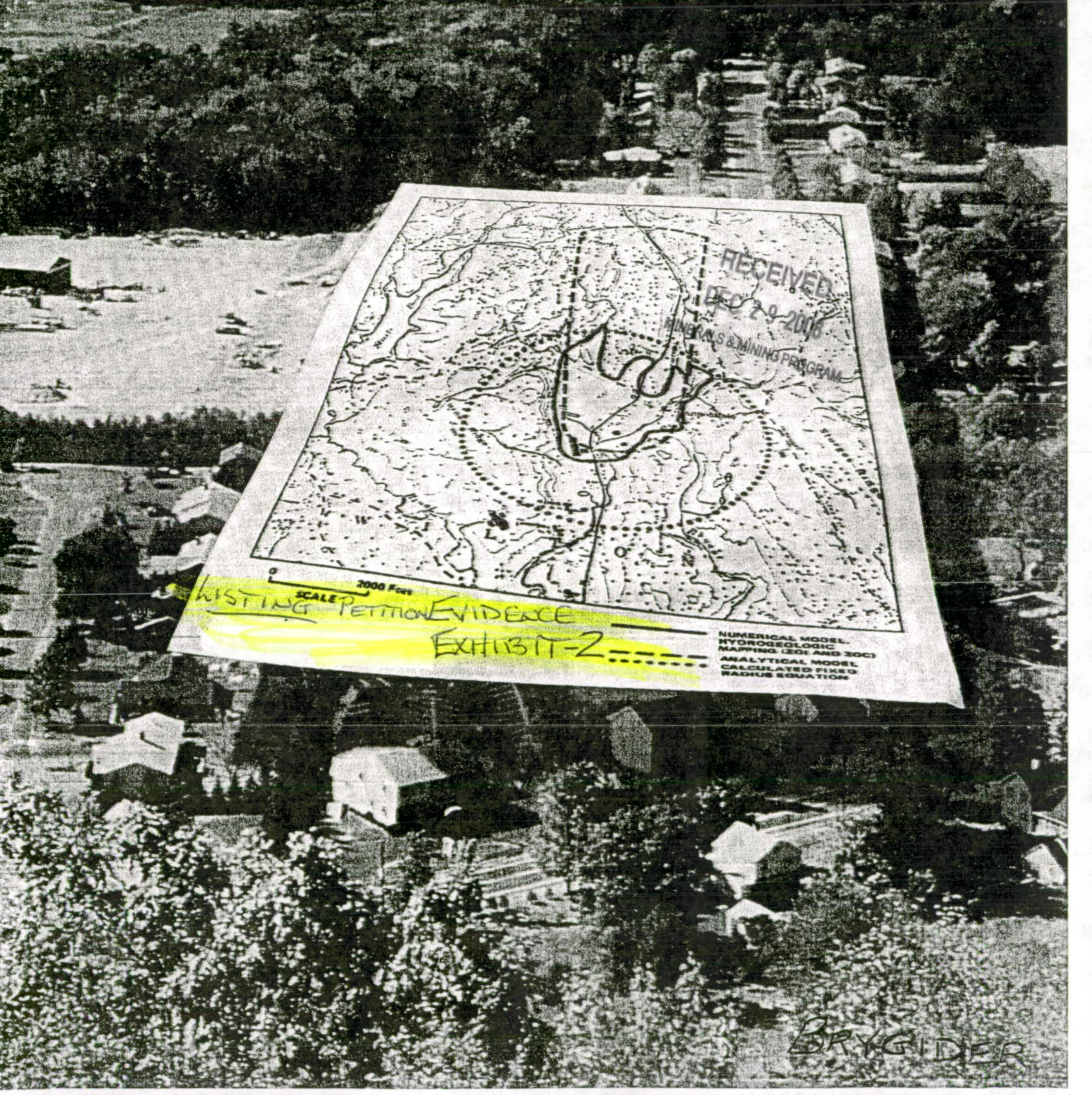

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Mining Activities

Active and abandoned mines can contribute to ground water contamination. Precipitation can leach soluble minerals from the mine wastes (known as spoils or tailings) into the ground water below. These wastes often contain metals, acids, minerals, and sulfides. Abandoned mines are often used as wells and waste pits, sometimes simultaneously. In addition, mines are sometimes pumped to keep them dry; the pumping can cause an upward migration of contaminated ground water, which may be intercepted by a well (U.S. EPA, 1990a).

Effects of Ground Water Contamination

Contamination of ground water can result in poor drinking water quality, loss of a water supply, high cleanup costs, high costs for alternative water supplies, and/or potential health problems. Some examples include:

- In Truro, Massachusetts, a leaking underground storage tank released gasoline into the aquifer in 1977. The wellfield in nearby Provincetown had to be closed to prevent contamination of the town's drinking water supply. More than $5 million was spent on aquifer rehabilitation. More than 13 years later, treatment was still required, and daily monitoring will be required for 3 years following the completion of the aquifer rehabilitation program.
- The public water supply wells in Atlantic City, New Jersey, were contaminated by leachate from a landfill; the city estimated that a new wellfield would cost approximately $2 million.
- In Minnesota, 17 cities have spent more than $24 million and 18 companies have expended more than $43 million because of ground water contamination (U.S. EPA, 1991d; U.S. EPA, 1990c).

Degradation or Destruction of the Water Supply

The consequences of a contaminated water supply often are serious. In some cases, contamination of ground water is so severe that the water supply must be abandoned as a source of drinking water. (For example, less than 1 gallon of gasoline can render 1 million gallons of ground water nonpotable [U.S. EPA, 1991c].) In other cases, the ground water can be cleaned up and used again, if the contamination is not too severe and if the municipality is willing to spend a good deal of money. Water quality monitoring is often required for many years.

Costs of Cleaning Up Contaminated Ground Water

Because ground water generally moves slowly, contamination often remains undetected for long periods of time. This makes cleanup of a contaminated water supply difficult, if not impossible. If a cleanup is undertaken, it can cost thousands to millions of dollars.

Once the contaminant source has been controlled or removed, the contaminated ground water can be treated in one of several ways:

- Containing the contaminant to prevent migration.
- Pumping the water, treating it, and returning it to the aquifer.
- Leaving the ground water in place and treating either the water or the contaminant.

A number of technologies can be used to treat ground water. They most frequently include air stripping, activated carbon adsorption, and/or chemical treatment with filtration. Different technologies are effective for different types of contaminants, and several technologies are often combined to achieve effective treatment. The effectiveness of treatment depends in part on local hydrogeological conditions, which should be evaluated prior to selecting a treatment option (U.S. EPA, 1990a).

Costs of Alternative Water Supplies

Given the difficulty and high costs of cleaning up a contaminated aquifer, some communities choose to abandon existing wells and use other water sources, if available. Using alternative supplies will probably be more expensive than obtaining drinking water from the original source. A temporary and expensive solution is to purchase bottled water, but this is not a realistic long-term solution for a community's drinking water supply problem. A community might decide to install new wells in a different area of the aquifer. In this case, appropriate siting and monitoring of the new wells are critical to ensure that contaminants do not move into the new water supplies.

Potential Health Problems

A number of microorganisms and thousands of synthetic chemicals have the potential to contaminate ground water. Table 3-4 lists some of these substances and their health risks. Drinking water containing bacteria and viruses can result in illnesses such as hepatitis, cholera, or giardiasis. Methemoglobinemia or "blue baby syndrome," an illness affecting infants, can be caused by drinking water high in nitrates. Benzene, a component of gasoline, is a known human carcinogen. The serious health effects of lead are well known: learning disabilities in children; nerve, kidney, and liver problems; and pregnancy risks. These and other substances are regulated by federal and state laws. Hundreds of other chemicals, however, are not yet regulated, and many health effects are unknown or not well understood. Preventing contaminants from reaching the ground water is the best way to reduce the health risks associated with poor drinking water quality.

Table 3-4. Health Risks Associated with Contaminated Ground Water

Substance	Major Sources	Possible Risk
Lead	Piping and solder in distribution system	Learning disabilities in children, nerve problems, birth defects
Fluoride	Geological	Crippling skeletal fluorosis, dental fluorosis
Metals	Geological, waste disposal practices	Liver, kidney, circulatory effects
Nitrate	Fertilizer, treated sewage, feedlots	Methemoglobinemia (Blue baby syndrome)
Microbiological Contaminants	Septic systems, overflowing sewer lines	Acute gastrointestinal illness, meningitis
Chlorinated Solvents	Industrial pollution, waste disposal practices	Cancer, liver, and kidney effects
Pesticides and Herbicides	Farming, horticultural practices	Nervous system toxicity, probable cancer
PCBs	Transformers, capacitors	Probable cancer, reproductive effects
Trihalomethanes	Treatment by-product	Liver, kidney damage, possible cancer
Asbestos	Geological, asbestos cement pipes	Tumors
Radon	Geological radioactive gas	Cancer

Source: Adapted from Metcalf & Eddy, 1989.

Regulations to Protect Ground Water

Several federal laws help protect ground water quality. *The Safe Drinking Water Act* (SDWA) establishes the Wellhead Protection Program and regulates the use of underground injection wells for waste disposal. It also provides EPA and the states with the authority to ensure that drinking water supplied by public water systems meets minimum health standards. *The Clean Water Act* regulates ground water shown to have a connection with surface water. It sets standards for allowable pollutant discharges. *The Resource Conservation and Recovery Act* (RCRA) regulates treatment, storage, and disposal of hazardous and non-hazardous wastes. *The Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA, or Superfund) authorizes the government to clean up contamination or sources of potential contamination from hazardous waste sites or chemical spills, including those that threaten drinking water supplies. CERCLA includes a "community right-to-know" provision. *The Federal Insecticide, Fungicide, and Rodenticide Act* (FIFRA) regulates pesticide use. *The Toxic Substances Control Act* (TSCA) regulates manufactured chemicals. The SDWA and RCRA are discussed in more detail below.

The Safe Drinking Water Act

As specified in the SDWA, EPA sets standards for maximum contaminant levels (the maximum permissible level of contaminant in water delivered to any user of a public water system) in public drinking water supplies, regulates underground disposal of wastes, designates sole-source aquifers, and establishes public water supply protection programs. By 1986, EPA had developed standards for 34 contaminants, including microorganisms, pesticides, radionuclides, volatile synthetic organic chemicals, and some heavy metals.

Amendments to the SDWA were passed in 1986 to enhance drinking water protection. These amendments included the Wellhead Protection Program and the Sole Source Aquifer Demonstration Program. EPA provides technical assistance to the states, which implement these two programs. The 1986 amendments also required EPA to set drinking water standards for 83 contaminants and for an additional 25 contaminants every 3 years. Table 3-5 lists current federal drinking water standards, expressed as maximum contaminant levels. In addition, the amendments required EPA to develop regulations for public drinking water systems to monitor unregulated contaminants.

Wellhead protection emphasizes the prevention of drinking water contamination as a principal goal, rather than relying on correction of contamination once it occurs. Under the SDWA, each state must prepare a Wellhead Protection Program and submit it to EPA for approval. Certain elements must be included in the program, but the law provides flexibility for states so that they can establish programs that suit local needs in protecting public water supplies. State wellhead protection programs must:

- Specify the roles and duties of state agencies, local government offices, and public water suppliers regarding development and implementation of the program.
- Delineate a wellhead protection area for each wellhead, based on hydrogeologic and other relevant information. Delineation criteria might include distance from the well, drawdown of water from the well, time of travel of water and/or contaminants to reach the well, hydrologeologic boundaries, and assimilative capacity (such as the ability of soils to keep contaminants from reaching ground water at unacceptable levels).
- Identify sources of contamination within each wellhead protection area.
- Develop management approaches (such as approaches for designating a lead agency; acquiring technical and financial assistance; and implementing training, demonstration projects, and education programs).
- Prepare contingency plans (plans for alternative drinking water supplies) for each public water supply system.
- Identify sites for new wells that would protect them from potential contamination.
- Ensure public participation.

Wellhead protection programs require the participation of all levels of government. The federal government (EPA) approves state wellhead protection programs and provides technical assistance, state governments develop and execute the programs, and local governmental bodies implement wellhead protection programs in their areas. Figure 3-3 shows states with approved wellhead protection programs.

The Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) regulates the storage, transport, treatment, and disposal of hazardous and solid wastes to prevent contaminants from leaching into ground water from municipal landfills, underground storage tanks, surface impoundments, and hazardous waste disposal facilities. The "cradle to grave" mandate of RCRA requires a trail of paperwork (a manifest document) to follow a hazardous waste from the point of generation, through transport and storage, to final disposal, to ensure proper handling of the wastes and provide accountability. RCRA includes technology re-

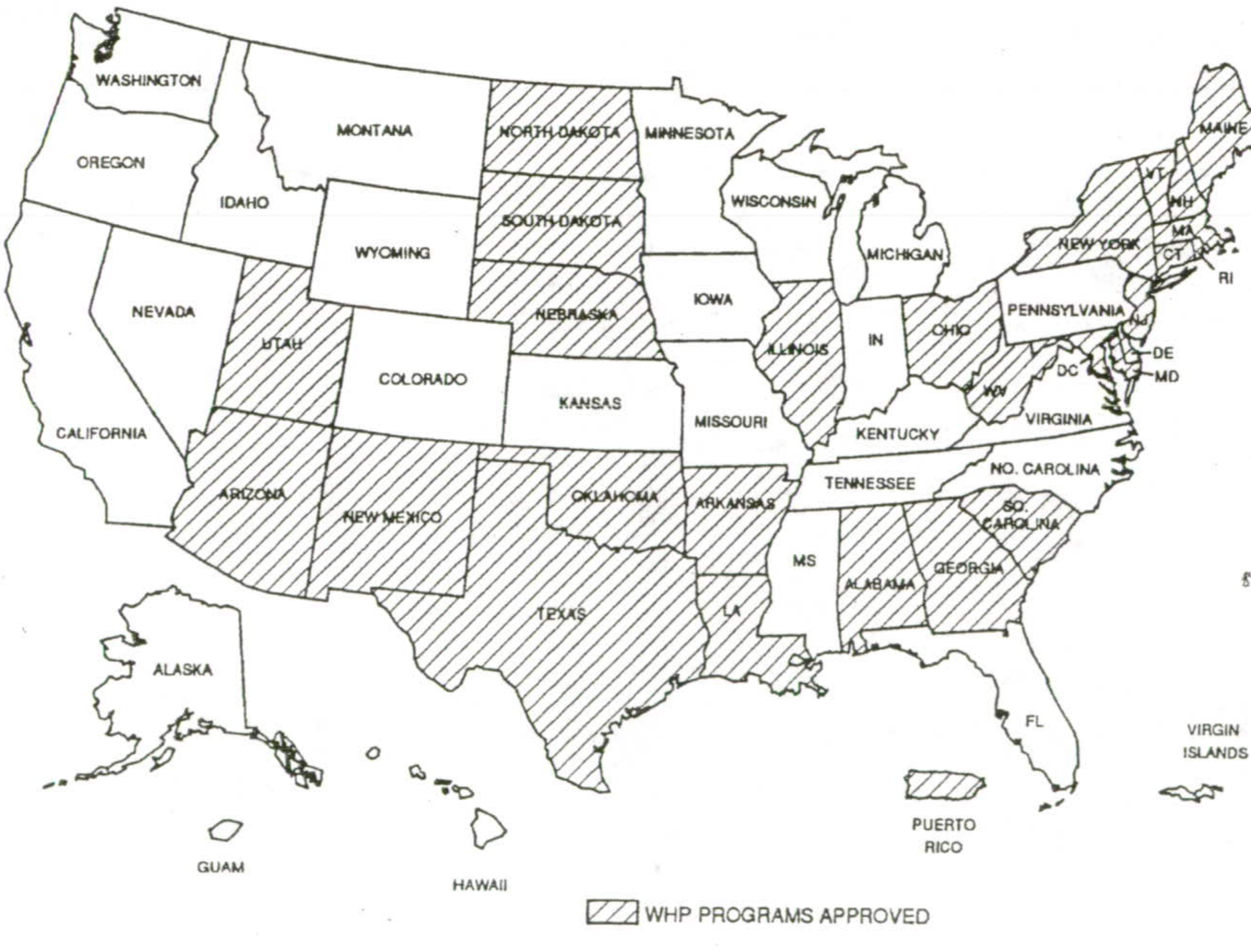

Figure 3-3. States with EPA-approved wellhead protection programs as of February 1993.

Table 3-5. Maximum Contaminant Levels (MCLs) for Drinking Water

Chemicals	Regulatory Status	MCL (mg/L)
ORGANICS		
Acrylamide	F	TT
Acrylonitrile	L	—
Adipates (diethylhexyl)	P	0.5
Alachlor	F	0.002
Aldicarb	F	0.003
Aldicarb sulfone	F	0.002
Aldicarb sulfoxide	F	0.004
Atrazine	F	0.003
Bentazon	L	—
Benz(a)anthracene (PAH)	P	0.0001
Benzene	F	0.005
Benzo(a)pyrene (PAH)	P	0.0002
Benzo(b)fluoranthene (PAH)	P	0.0002
Benzo(k)fluoranthene (PAH)	P	0.0002
Bromacil	L	—
Bromobenzene	L	—
Bromochloroacetonitrile	L	—
Bromodichloromethane (THM)	L	0.1
Bromoform (THM)	L	0.1
Bromomethane	L	—
Butyl benzyl phthalate (PAE)	P	0.1
Carbofuran	F	0.04
Carbon tetrachloride	F	0.005
Chloral hydrate	L	—
Chlordane	F	0.002
Chlorodibromomethane (THM)	L	0.1
Chloroethane	L	—
Chloroform (THM)	L	0.1
Chloromethane	L	—
Chloropicrin	L	—
Chlorotoluene o-	L	—
Chlorotoluene p-	L	—
Chrysene (PAH)	P	0.0002
Cyanazine	L	—
Cyanogen chloride	L	—
2, 4-D	F	0.07
DCPA (Dacthal)	L	—
Dalapon	P	0.2
Di[2-ethylhexyl]adipate	P	0.4
Dibenz(a,h)anthracene (PAH)	P	0.0003
Dibromoacetonitrile	L	—
Dibromochloropropane (DBCP)	F	0.0002
Dibromomethane	L	—
Dicamba	L	—
Dichloroacetaldehyde	L	—
Dichloroacetic acid	L	—
Dichloroacetonitrile	L	—
Dichlorobenzene o-	F	0.6
Dichlorobenzene m-[a]	F	0.6
Dichlorobenzene p-	F	0.075
Dichlorodifluoromethane	L	—
Dichloroethane (1,1-)	L	—
Dichloroethane (1,2-)	F	0.005
Dichloroethylene (1,1-)	F	0.007
Dichloroethylene (cis-1,2-)	F	0.07
Dichloroethylene (trans-1,2-)	F	0.1
Dichloromethane	P	0.005
Dichloropropane (1,2-)	F	0.005
Dichloropropane (1,3-)	L	—
Dichloropropane (2,2-)	L	—
Dichloropropene (1,1-)	L	—
Dichloropropene (1,3-)	L	—
Diethylhexyl phthalate (PAE)	P	0.004
Dinitrotoluene (2,4-)	L	—
Dinitrotoluene (2,6-)	L	—
Dinoseb	P	0.007
Diquat	P	0.02
Endothall	P	0.1
Endrin	P	0.002
Epichlorohydrin	F	TT
Ethylbenzene	F	0.7
Ethylene dibromide (EDB)	F	0.00005
ETU	L	—
Fluorotrichloromethane	L	—
Glyphosate	P	0.7
Heptachlor	F	0.0004
Heptachlor epoxide	F	0.0002
Hexachlorobenzene	P	0.001
Hexachlorobutadiene	L	—
Hexachlorocyclopentadiene	P	0.05
Hexachloroethane	L	—
Hypochlorite	L	—
Indeno(1,2,3,-c,d)pyrene (PAH)	P	0.0004
Isophorone	L	—
Lindane	F	0.0002
Methomyl	L	—
Methoxychlor	F	0.04
Methyl tert butyl ether	L	—
Metolachlor	L	—
Metribuzin	L	—
Monochloroacetic acid	L	—
Monochlorobenzene	F	0.1
Oxamyl (Vydate)	P	0.2

Table 3-5. Maximum Contaminant Levels (MCLs) for Drinking Water (continued)

Chemicals	Regulatory Status	MCL (mg/L)
Ozone by-products	L	—
Pentachlorophenol	F	0.001
Picloram	P	0.5
Polychlorinated biphenyls (PCBs)	F	0.0005
Prometon	L	—
Simazine	P	0.004
Styrene	F	0.1
2,3,7,8-TCDD (Dioxin)	P	5E-08
2,4,5-T	L	—
Tetrachloroethane (1,1,2,2-)	L	—
Tetrachloroethylene	F	0.005
Toluene	F	1
Toxaphene	F	0.003
2,4,5-TP	F	0.05
Trichloroacetic acid	L	—
Trichloroacetonitrile	L	—
Trichlorobenzene (1,2,4-)	P	0.07
Trichloroethane (1,1,1-)	F	0.2
Trichloroethane (1,1,2-)	P	0.005
Trichloroethanol (2,2,2-)	L	—
Trichloroethylene	F	0.005
Trichlorophenol (2,4,6-)	L	—
Trichloropropane (1,2,3-)	L	—
Trifluralin	L	—
Vinyl chloride	F	0.002
Xylenes	F	10
INORGANICS		
Aluminum	L	—
Antimony	P	0.006
Arsenic	—[c]	0.05
Asbestos (fibers/l>10 µm length)	F	7 MFL
Barium	F	2
Beryllium	P	0.001
Boron	L	—
Cadmium	F	0.005
Chloramine	L	—
Chlorate	L	—
Chlorine	L	—
Chlorine dioxide	L	—
Chlorite	L	—
Chromium (total)	F	0.1
Copper	F	TT[b]
Cyanide	P	0.2
Fluoride[c]	F	4
Lead (at tap)	F	TT[b]

Chemicals	Regulatory Status	MCL (mg/L)
Manganese	L	—
Mercury (inorganic)	F	0.002
Molybdenum	L	—
Nickel	P	0.1
Nitrate (as N)	F	10
Nitrite (as N)	F	1
Nitrate + Nitrite (both as N)	F	10
Selenium	F	0.05
Strontium	L	—
Sulfate	P	400/500
Thallium	P	0.002
Vanadium	L	—
Zinc	L	—
Zinc chloride (measured as Zinc)	L	—
RADIONUCLIDES		
Beta particle and photon activity (formerly man-made radionuclides)	F	4 mrem
Gross alpha particle activity	F	15 pCi/L
Radium 226/228	P	5 pCi/L
Radon	P	300 pCi/L
Uranium	P	20 µg/l
MICROBIOLOGY		
Cryptosporidium	L	—
Giardia lamblia	F	TT
Legionella	F[d]	TT
Standard Plate Count	F[d]	TT
Total Coliforms (after 12/31/90)	F	**
Turbidity (after 12/31/90)	F	PS
Viruses	F[d]	TT

[a]The values for m-dichlorobenzene are based on data for o-dichlorobenzene.

[b]Copper — action level 1.3 mg/L; Lead — action level 0.015 mg/L.

[c]Under review.

[d]Final for systems using surface water; also being considered for regulation under ground water disinfection rule.

Key:

F - final
L - listed for regulation
P - proposed (Phase II and V proposals)
PS - performance standard 0.5 NU - 1.0 NU
TT - treatment technique
MFL - million fibers per liter
** - No more than 5% of the samples per month may be positive. For systems collecting fewer than 40 samples/month, no more than 1 sample per month may be positive.

Source: U.S. Environmental Protection Agency, Office of Water, *Drinking Water Regulations and Health Advisories*, November 1992.

EXHIBIT 3

South Dakota

GREAT FACES. GREAT PLACES.

DEPARTMENT OF GAME, FISH AND PARKS
Cleghorn Fish Hatchery
4725 Jackson Boulevard
Rapid City, South Dakota 57702-4804

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October 17, 2008

SD/DENR Minerals and Mining Program
Attn. Roberta Fivecoate
Joe Foss Building
523 East Capitol Avenue
Pierre, SD 57501-3181

SUBJECT: Powertech Inc. exploration notice of intent Fall River and Custer Counties

South Dakota Game, Fish and Parks is reviewing information in response to the notice. Resulting from our review, we recommend the following actions for the project:

- At sections 30 & 29 T6S-R1E, conduct exploration activity before February or after August to avoid disruption of bald eagle activity at the nest located near the middle of the SW1/4 section 30, and the redtail hawk nest near SENE section 29.

- Contact me at the any of the numbers listed if exploration activity is conducted between February 1st and August 31 in sections 30 & 29 T6S-R1E. Please be advised that GFP recommendations during this period may include distance and/or timing restrictions.

If you have any questions please contact me by any of the numbers listed below

Sincerely,

Stan Michals
Energy and Minerals Coordinator

Office (605) 394-2589
Fax (605) 394-1760
E-mail stan.michals@state.sd.us

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